

BELLCOMM, INC.

1100 Seventeenth Street, N.W. Washington, D. C. 20036

SUBJECT: Manned Lunar Program Options -
Mission Equipment - Case 230

DATE: Sept. 29, 1967

FROM: C. Bendersky
D. R. Valley

ABSTRACT

This memorandum contains descriptive material on the mission equipment assembled during the Manned Lunar Program Options Study. Mission equipment refers to lunar shelters, mobility systems, and landing vehicles for logistics delivery. The equipment spectrum ranges through two generations of Apollo equipment as well as new equipment concepts under study. Equipment weights, capabilities, and required modifications are included along with some anticipated problem areas and improvement items that might be considered.

The information was assembled primarily through review of NASA sponsored studies; however, results of contacts with the centers and various Apollo contractors are also incorporated.

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MEMORANDUM FOR FILE

1.0 INTRODUCTION

This memorandum contains descriptive information on the spectrum of mission equipment included in the Manned Lunar Program Options Study. Mission equipment, as used herein, includes shelters, mobility systems, and landing vehicles for logistics payloads. The equipment spectrum is presented in two basic categories--Apollo derivative equipment and new equipment. The time and manpower limitations of the study precluded detailed analysis of these equipment items and thus effort was concentrated on major capabilities and equipment weights.

The information presented herein was used as source data for the Manned Lunar Program Options--Mission Modes report (Reference 1). The data was current up to June 30, 1966.

2.0 APOLLO DERIVATIVE EQUIPMENT

The candidate Apollo derivative equipment cannot be discussed in terms of minor modifications because in no event are the modifications minor in scope or cost. Table 1 contains a listing of the equipment items included in this category along with a brief summary of the pertinent features outlined in the following discussions.

2.1 LM Shelter

The LM shelter concept (Figure 1) is the simplest proposed Apollo derivative shelter and has been considered for use in several AAP flights. The concept combines logistics and crew quarters in one vehicle by stripping out the present LM ascent stage main propulsion system and adding suitable expendables and experimental payloads. The flight plan assumes a manned Command Service Module (CSM), Lunar Orbit Rendezvous (LOR) mode. The LM shelter is landed by remote control from the manned CSM which is then returned to earth. The LM shelter

to develop a new pump-fed engine or use a converted Agena engine² and take advantage of the superior performance available.

2.4 CM Lunar Shelter

The CM could be converted into a lunar shelter (Figure 15) by removal of the heat shield, interior modification, addition of a fuel cell power supply, storage facilities for fuel cell reactants and life support expendables, and (possibly) some type of airlock. When compared to a LM derivative shelter, the greatest advantage of the CM is the 36% greater available volume--306 ft³ compared to 225 ft³. Quiescent storage capability modifications will be similar to those required for lunar orbit CM modes, possibly with the exception of larger RTG requirements for thermal control.

2.5 LASS Concept

The Douglas Company (DAC) has proposed the "Lunar Application of a Spent S-IVB Stage (LASS)" (Reference 4). The LASS concept requires a landing gear on a S-IVB Stage. The mission is an unmanned, direct-flight, using an existing lunar beacon to obtain a precise landing location. The LASS requires either a highly throttleable J-2 type engine (J-2X) or a moderately throttleable J-2S with RL-10 engines added to provide proper landing control. DAC studied several configurations and recommended that of Figure 4 consisting of a vertical lander with a payload package on top. Landed payloads in the order of 24,000 lbs were claimed by DAC with the 1965 Saturn V capability. This payload was based on a more optimistic ΔV budget than used in this study; however, the landed payload would still be substantial (16,000 - 19,000 lbs) using the more conservative values. An evaluation of the LASS concept (Reference 5) was performed as part of this study effort.

2.6 MOLEM - Mobile LM Shelter

Third generation versions of LM derivative equipment have been studied (Reference 2) where the LM shelter is further modified to become a mobile shelter (MOLEM); thereby eliminating the need for a separate lunar roving vehicle (LRV). Two versions were studied; a "minimum" change (four wheel vehicle) and "moderate" change (four wheel vehicle plus two wheel trailer). Figure 5 presents a line schematic of the minimum change version.

²The Air Force is presently funding conversion of the Agena Engine to Apollo propellants for use in 1970.

is intended to support two men for 14 days, including extra-vehicular activity (EVA). The shelter will have 90 days quiescent storage capability prior to usage. A 50 watt radio-isotope thermoelectric generator (RTG) is provided for thermal control. Two Allis Chalmers (2 kw) fuel cells are provided for an electrical power system (EPS). Fuel cell reactants are supplied from ambient temperature high pressure bottles. In this configuration, the LM shelter weight is approximately 6700 lbs.

Based on a later Grumman study (Reference 2), substitution of cryogenic H_2/O_2 storage for the present ambient temperature high pressure storage could reduce the shelter weight approximately 1000 lbs¹ at some cost in development time and (possibly) reliability.

2.2 LM Truck

The LM Truck concept (Figure 2) uses a modified LM descent stage as a Lunar Logistic Vehicle (LLV). The LM ascent stage is removed and replaced by a cargo platform. Subsystems now on the LM ascent stage which are necessary for landing (e.g., reaction control system (RCS) and guidance) are added. The Truck is usually associated with the flight plan previously described for LM Shelter (manned CSM); however, a totally unmanned flight mode is possible with proper guidance and navigation modification. As presently conceived, the LM Truck weighs 22,200 lbs and has the same propellant capacity and payload capability as the present LM descent stage. The LM Truck capability would benefit from an "augmented" LM development discussed in Reference 1.

2.3 SM Logistic Lander

North American Aviation (NAA) has proposed use of the SM as a lunar logistics vehicle (LLV) (Reference 3). The configuration (Figure 3), simply stated, puts a landing gear on the SM. It was proposed for use in an unmanned, direct landing mode. The concept was not critically evaluated during this study; however, NAA claims the capability of 11,000 lbs landed payload. The system requires the addition of remote guidance and control and a suitable throttling engine. So-called "conversions" of the present SM engine really infer a new engine development, probably of the same magnitude as that required for the present LM descent engine. It probably would be wiser

¹As also stated in Reference 2, much of this advantage could be reduced by development of filament-wound tankage for ambient high pressure storage.

Table 2 summarizes the two configurations. The MOLEM was designed to support two men for 14 days and traverse 250 nm in a 50 nm radius. EVA is the same as for the LM Shelter mission. The flight mode is an LOR using a manned CSM to control lunar landing. The MOLEM could be used on either a modified LM descent stage or a LM Truck.

Pertinent additions are Allis Chalmers fuel cells (total 8 kw), a deployable (collapsible) airlock, and a three month quiescent storage capability. Two 50 watt RTG's are required for quiescent storage. The study assumed high pressure ambient temperature oxygen/hydrogen storage, but also evaluated a cryogenic system which resulted in weight savings in the order of 750 to 1,000 lbs and provided additional volume for experimentation at some cost in development time and (possibly) reliability.

2.7 Mobile Command Module - MOCOM

In similar fashion to the MOLEM, third generation versions of the CM have been studied (Reference 6) to further modify a CM shelter to provide mobility. A typical configuration is presented in Figure 6. Essentially the CM is mounted on a four wheel chassis. For the same mobility mission as MOLEM, the MOCOM weighs about 9,500 lbs. Power is supplied primarily by fuel cells using cryo stored reactants. An RTG provides power needs for quiescent storage.

3.0 NEW EQUIPMENT

The new logistic supply and shelter equipment are strictly conceptual and as such are not limited in scope as with Apollo derivations. Evaluations of new equipment in terms of new lunar shelters, advanced logistic carriers and lunar mobility systems have been continuously under study by NASA. Therefore, the systems will be discussed in terms of general study philosophy and parametric results.

3.1 Early Lunar Shelter (ELS)

New equipment shelter capabilities were based on the results of the recently completed Early Lunar Shelter Study (ELS) by AiResearch, (Reference 7). The study was an evaluation of configurations suitable for use with LM Truck capability (10,300 lbs). The primary objective was the evaluation and conceptual design of two-man lunar shelters for comparison with competing concepts such as the LM Shelter. This was later expanded to include evaluation of three-man shelters.

Staytime capabilities were evaluated in terms of crew size, and duty cycles with and without EVA activity. Both two and three man crews were considered, and the EVA duty cycle consisted of 9 hours/day; 6 hours (one man) on a "Local Scientific Survey Module" (LSSM) and a non-concurrent 3 hour EVA on foot in the ELS vicinity. Based on the above, expendable consumption rates were established for crew metabolism, environmental control and life support (EC/LSS), electrical power supply (EPS) and fluid storage. It was concluded that a minimum design volume of 500 ft³ was desirable for a two man, 14 day mission. Final designs were based on a 750 ft³ volume. Basic shelter equipments included rechargeable portable life support systems (PLSS) (3 per man), fuel cells for EPS, cryogenic supercritical storage for fuel cell reactants and life support gases and LiOH for CO₂ removal. Figure 7 summarizes the study results. Note the staytime capability of 50 days for two men. Figure 8 presents a typical schematic, and Figure 9 a weight breakdown of the ELS optimized for a three man crew.

3.2 Local Scientific Survey Module (LSSM)

The LSSM is a small size vehicle used to support a local manned survey. It is proposed for delivery with a LM Shelter. The typical, one-man configuration shown in Figure 10 weighs in the order of 1,000 lbs, is battery powered and has a total range capability of 200 km per mission, an operating range of 8 km, and a minimum speed capability of 4 km per hour. The crew sits in an open cockpit.

3.3 Mobile Laboratories - MOLAB

The moderate capacity mobile laboratory (MOLAB) concept was studied in two NASA/MT contracts (References 8 and 9) to determine configurations and capabilities of vehicles in the 6,500 to 8,500 lb class. Designed for delivery by the LM Truck, MOLAB was to be capable of surviving six months quiescent storage on the lunar surface, and then be activated to support a two man 14 day mission with a 7 day staytime contingency in a stationary mode. Figure 11 presents a typical configuration consisting of a four wheel vehicle having an internal pressurized volume of 452 ft³ plus an additional 122 ft³ airlock. The MOLAB would take advantage of any subsystem improvements evaluated in the ELS studies such as cryogenic gas storage systems. In essence, a MOLAB relates to an ELS as the MOLEM to the LM shelter. Staytime or experimental payload is traded for mobility.

Although the MOLAB was sized for a two man, 14 day mission, the concept can be scaled from the parametric data of Reference 6 to establish tradeoffs of crew size and stay-time in terms of weight and subsystem requirements. Figure 12 is a typical data sheet for a three man, 21 day, 488 nm traverse which requires a MOLAB weighing 8,400 lbs.

3.4 Lunar Logistic Vehicle (LLV)

In the past, many versions of new LLV's using several possible candidate propellants have been studied. For the time span of this study, it was decided to limit the candidates to those being used in active NASA programs; that is, earth storables of the N_2O_4 /Aerozene 50 and cryogenics of the LO_2/LH_2 ³ types. The choice between the two revolves about a tradeoff between 33% better I_{sp} performance, poorer length to diameter configurations, and more extensive ground support requirements of LO_2/LH_2 compared to N_2O_4 /Aerozene 50. However, the performance increase does provide significantly larger payload capabilities, and accordingly, the cryogenic combination was chosen for the new LLV's.³ In addition to the conventional one stage configurations, two stage versions are also of interest. A typical two stage LLV consists of a braking stage (LI) and a landing stage (LII). The advantages of staging are (1) payload improvement, (2) the landed vehicle has a lower center-of-gravity (reducing possible cargo unloading problems and landing gear requirements), and (3) the braking stage (LI) can be a general use propulsion stage for integration into earth orbital or planetary programs (Multi-Mission Module Concept). Typical configurations of single and two stage LLV's are shown in Figures 13 and 14 as obtained from Reference 10).

4.0 CONCLUDING REMARKS

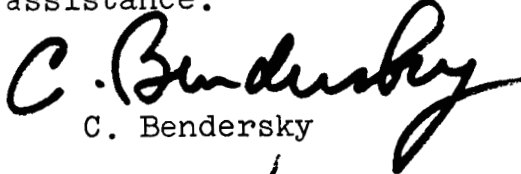
The capabilities of the mission equipment and concepts distributed in this memo were used as source material for Task Order 30 study effort during the first half of 1966.

³If an acceleration of fluorine technology state-of-the-art results in a more general level of acceptance of LF_2 for use in NASA programs, and if other concomitant programs make LF_2/LH_2 engines available (RL10 AF series) the substitution of a LF_2 stage for a LO_2 stage should be considered. The stage would have a small I_{sp} improvement but a considerably better length to diameter ratio and structural mass fraction.

For future use, the data should be reviewed and revised as warranted. It is suggested that the authors be contacted for additional information or for more recent study results.

ACKNOWLEDGEMENTS

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1013-CB
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Attachments
References
Figures 1 - 15
Tables 1 and 2

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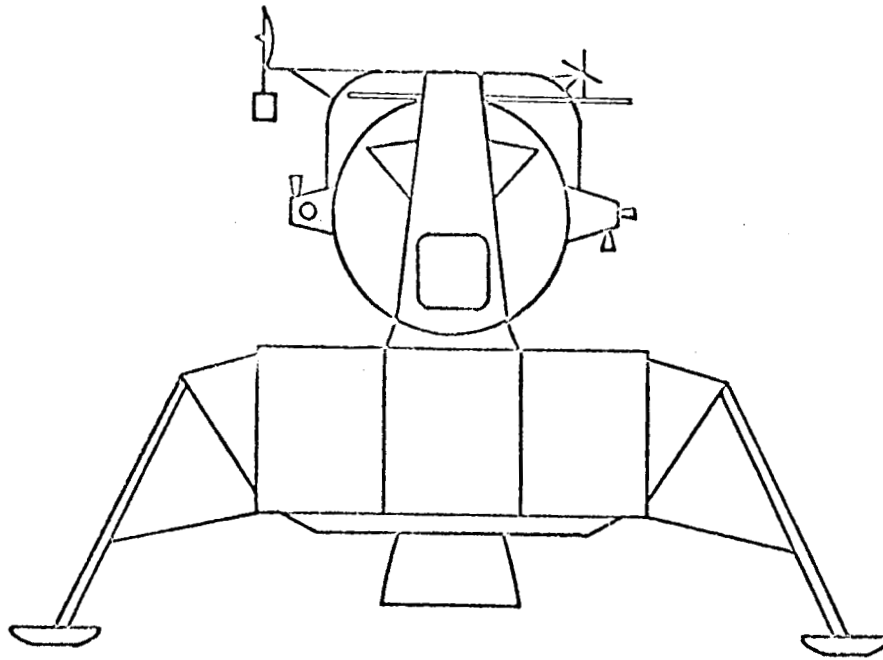


FIGURE 1 - LM SHELTER CONFIGURATION

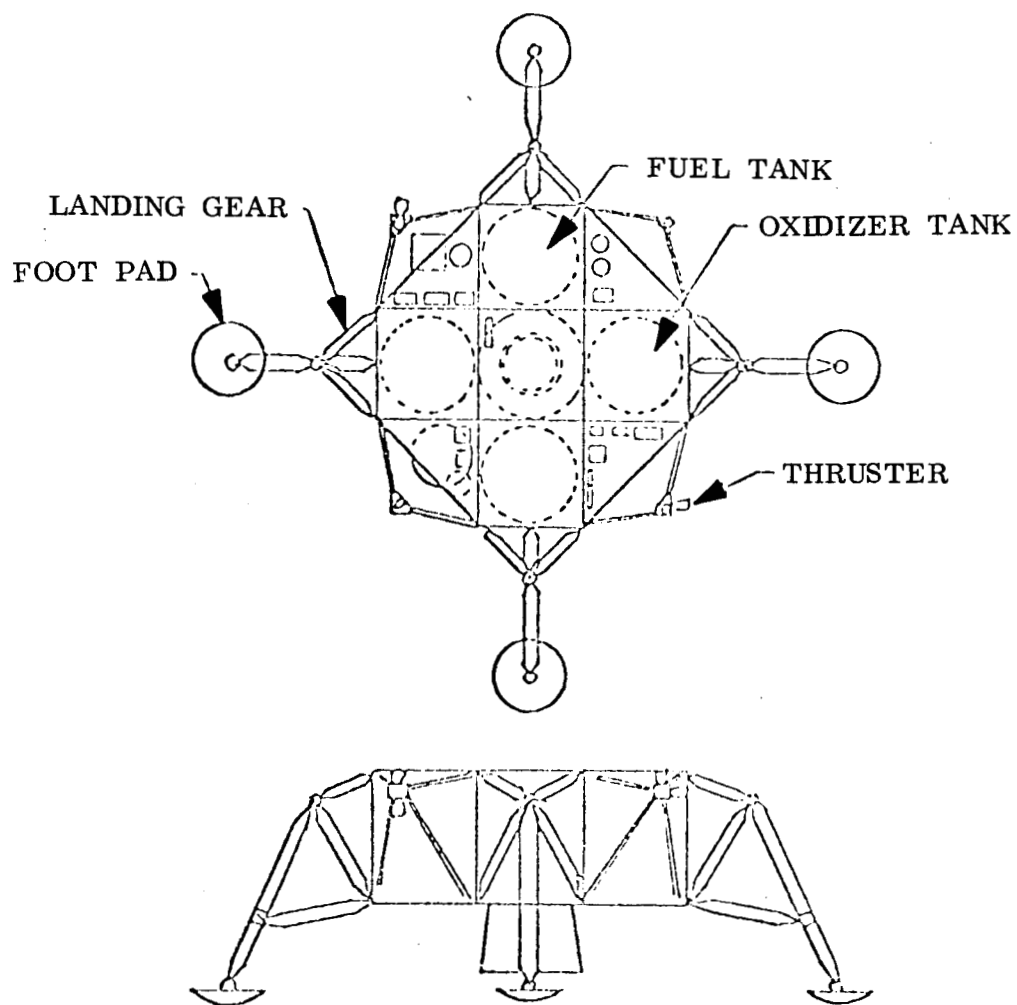


FIGURE 2 - LM TRUCK CONCEPT

FEATURES

- SIMPLE MISSION CONFIGURATION
 - STRAIGHTFORWARD DEVELOPMENT
 - SUBSTANTIAL PAYLOAD CAPACITY AT EARLY OPERATIONAL DATE
- 11,070 LB LANDED WITH BLOCK 1 SM
- 16,400 LB WITH EXTENDED SM

PROBLEM AREAS

- EXTENDED VERSION REQUIRES 42 IN. LENGTH ADDED
- DESIGN LANDING GEAR & THROTTLING ENGINE PROVISIONS
- REMOTE GUIDANCE & CONTROL

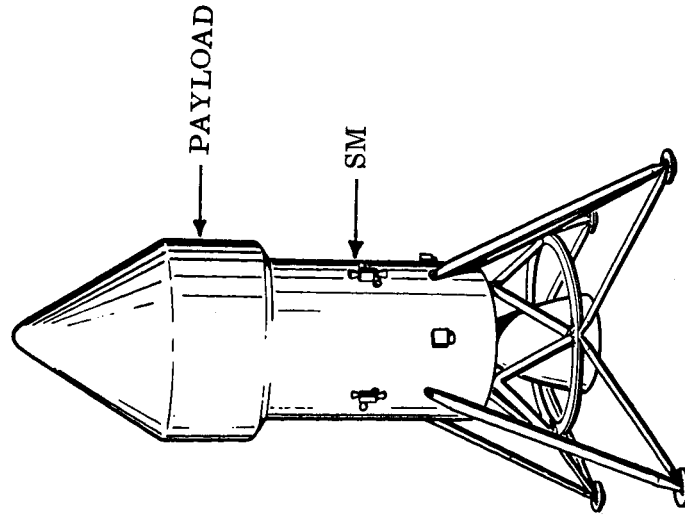
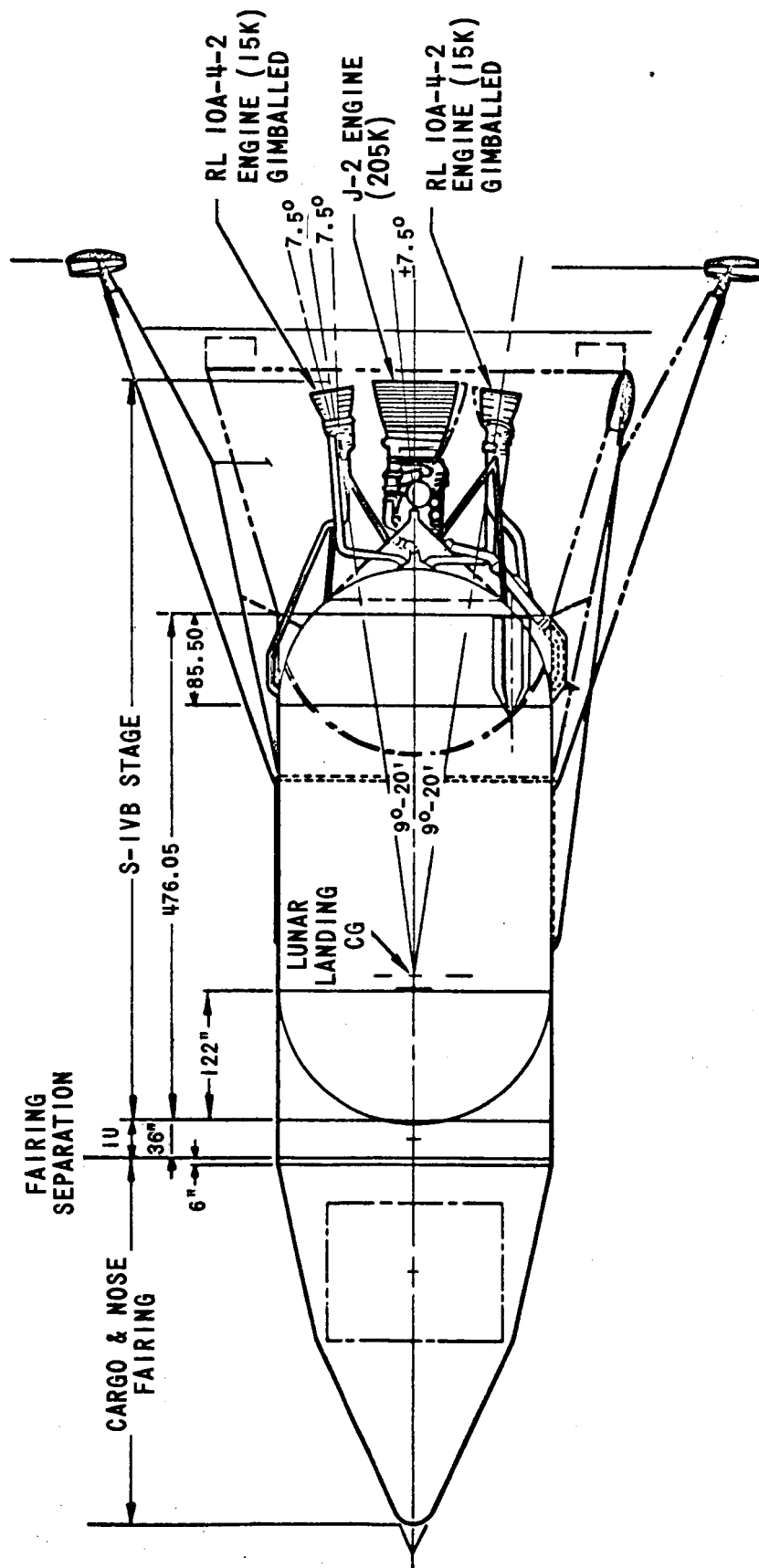


FIGURE 3 - EARLY DIRECT MISSION LOGISTIC SM LANDER



NOTE: GUIDE RAILS NEEDED TO
 PROVIDE RL 10A-4-2
 CLEARANCE WITH INTERSTAGE
 SEPARATION.

FIGURE 4 - LASS (LUNAR LOGISTICS VEHICLE) MODIFICATION OF S-IVB
 J2-S/2-RL-10 CONFIGURATION

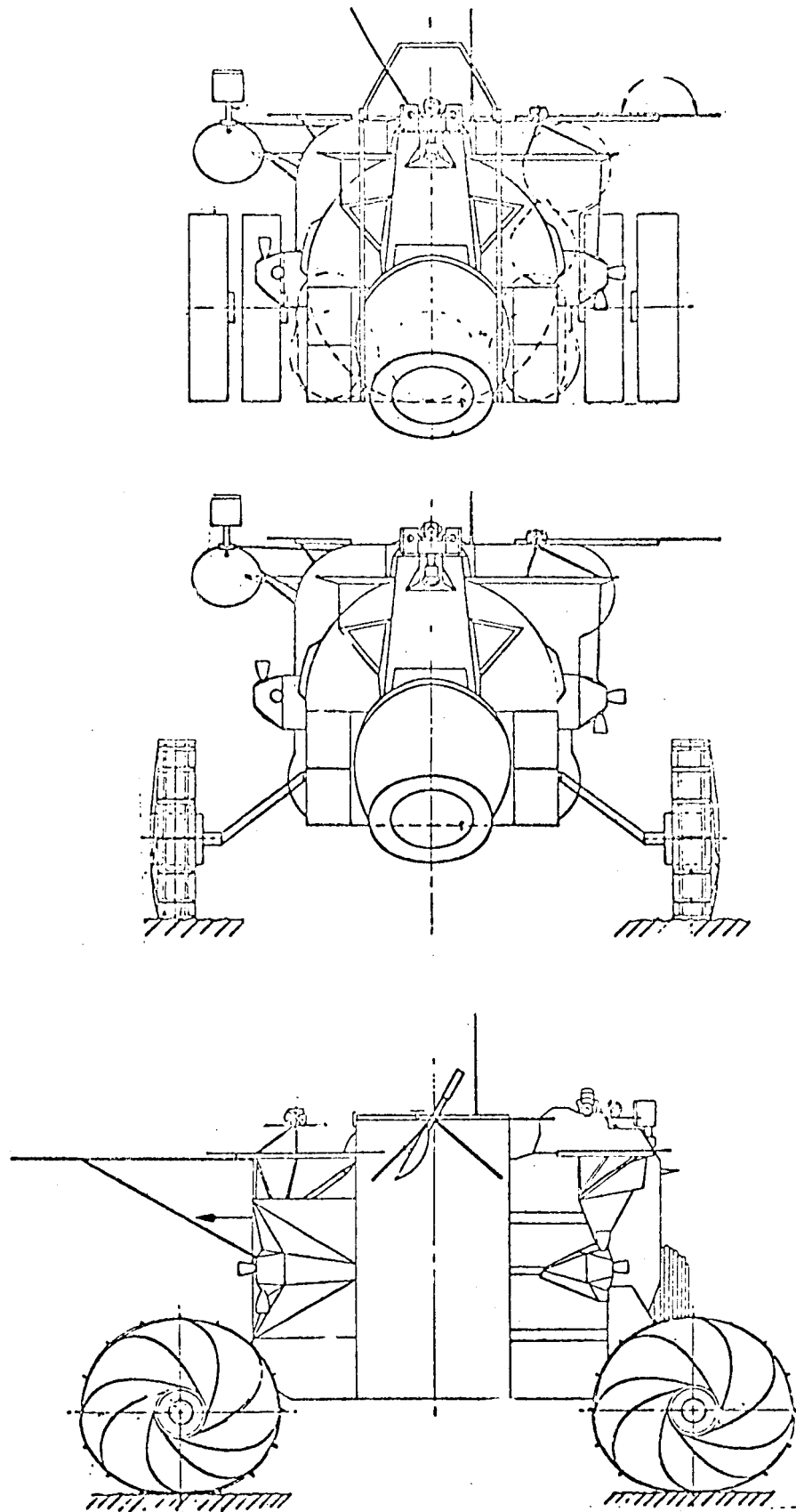
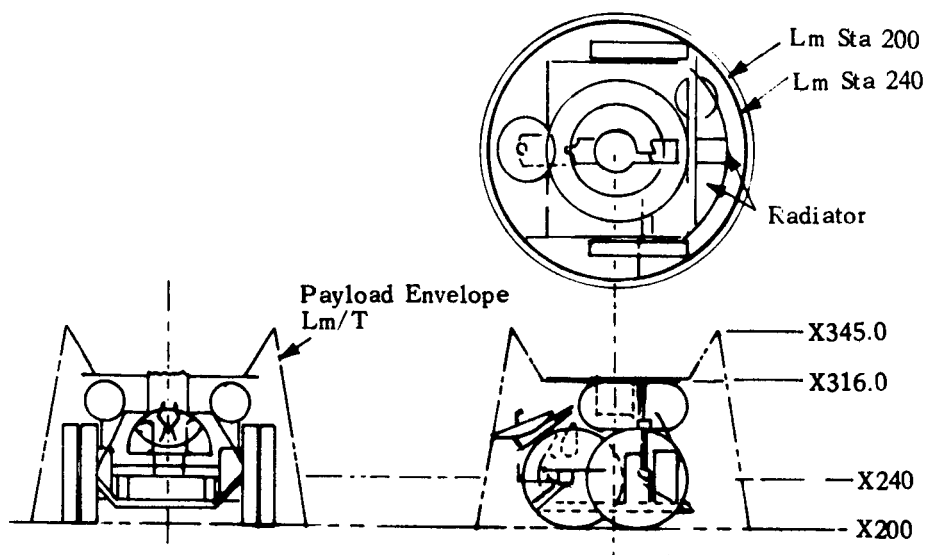
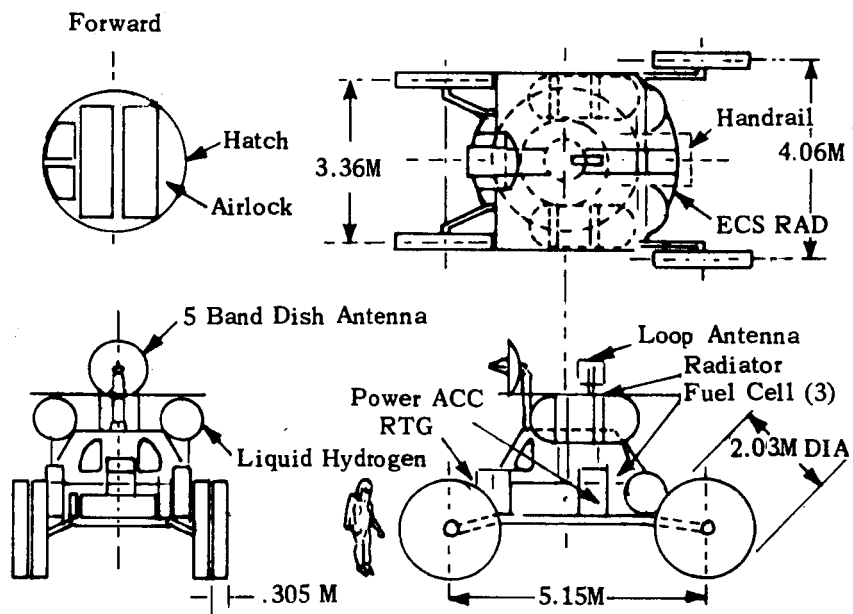


FIGURE 5 - MINIMUM - CHANGE MOLEM
CONFIGURATION (GRUMMAN)



Launch Configuration



System External Layout

FIGURE 6 - MOCOM CONCEPT

- 50 DAYS LUNAR STAYTIME WITH TWO-MAN CREW
- 787 MAN-HR AVAILABLE FOR SCIENTIFIC MISSION
 - 450 MAN-HR EXTRA-SHELTER ACTIVITY
 - 337 MAN-HR IN-SHELTER ACTIVITY
- 1578 KG (3470 LB) SCIENTIFIC EQUIPMENT PAYLOAD
- 600 KW-HR ELECTRICAL ENERGY PROVIDED BY SHELTER FOR SUPPORT OF SCIENTIFIC MISSION
- 912 KM LUNAR SURFACE TRAVERSE WITH LSSM
- DEPLOY EMPLACED SCIENTIFIC STATION AND SATELLITES
- DRILL 100 FT HOLE IN SITU
- 43 DAYS LUNAR STAYTIME CAPABILITY WITH THREE-MAN CREW (1050 MAN-HR AVAILABLE FOR SCIENTIFIC MISSION)
- 66 DAYS LUNAR STAYTIME CAPABILITY WITH TWO-MAN CREW AND OAP TELESCOPE PAYLOAD

FIGURE 7 - RESULTS OF EARLY LUNAR SHELTER STUDY

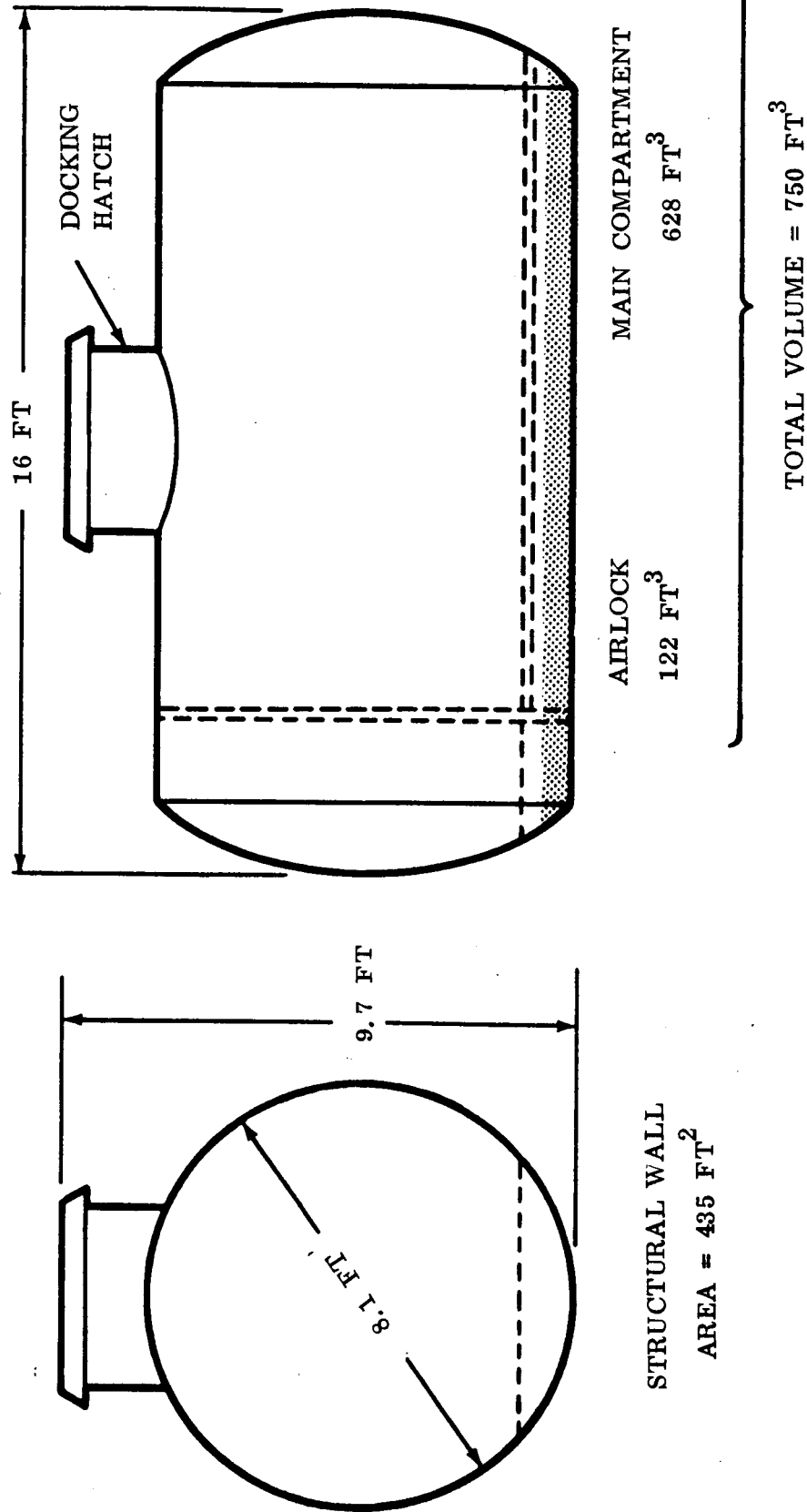


FIGURE 8 - SCHEMATIC EARLY LUNAR SHELTER

FIXED EQUIPMENT		EXPENDABLES	
STRUCTURE	1345 LB	FOOD	244 LB
EPS	746	WATER	228
FLUID STORAGE	625	PLSS CANISTERS	593
EC/LSS	699	HIGH-PRESS. O ₂	125
CREW PROVISIONS	521	CRYOGENIC O ₂	1269
ASTRIONICS	240	HYDROGEN	132
SCIENTIFIC EQUIPMENT	3470	PERS. HYG./WASTE MAN.	117
TOTAL	7646 LB	TOTAL	2654 LB
TOTAL PAYLOAD = 10,300 LB			

FIGURE 9 - 3-MAN SHELTER, 3 MEN, 9 HR ESA, 43 DAY STAYTIME WEIGHT SUMMARY

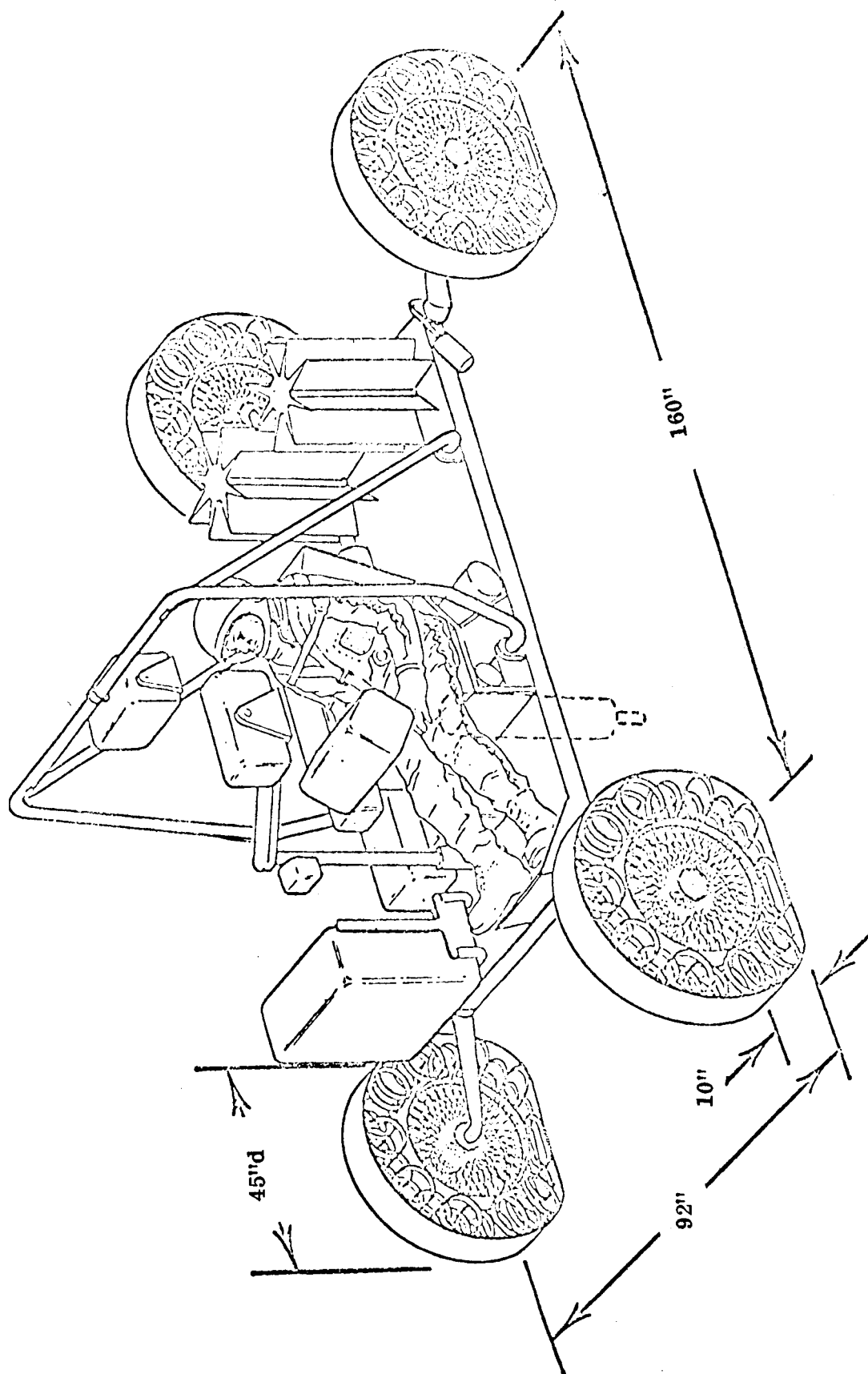


FIGURE 10 - TYPICAL LSSM CONFIGURATION

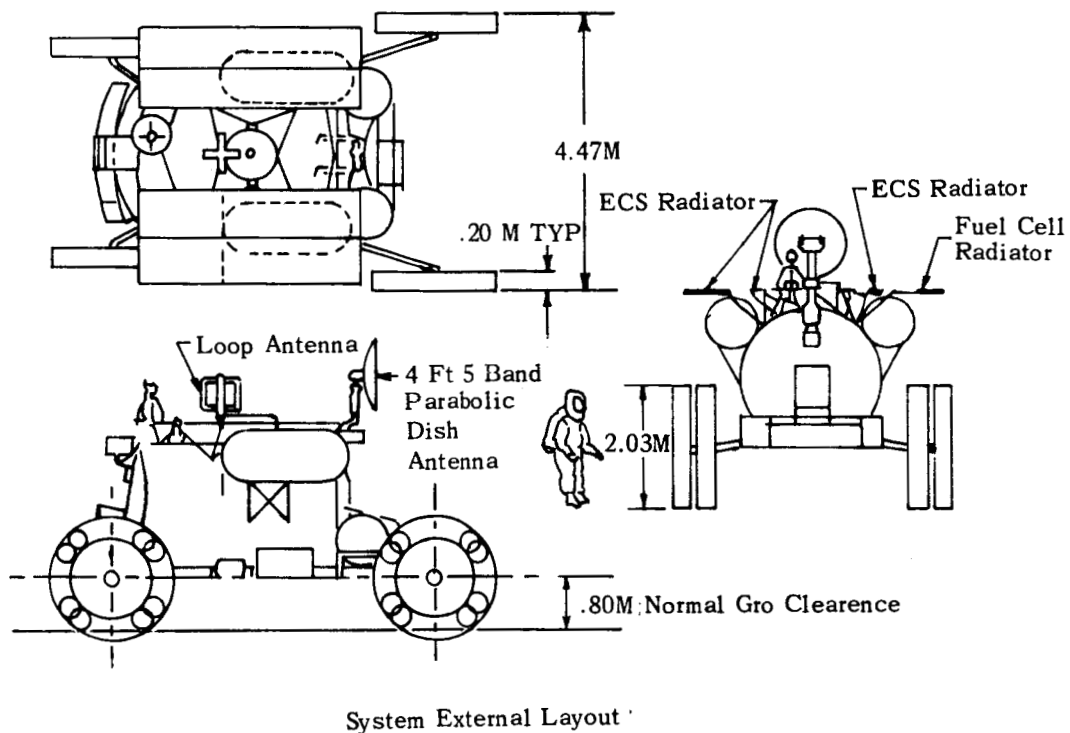
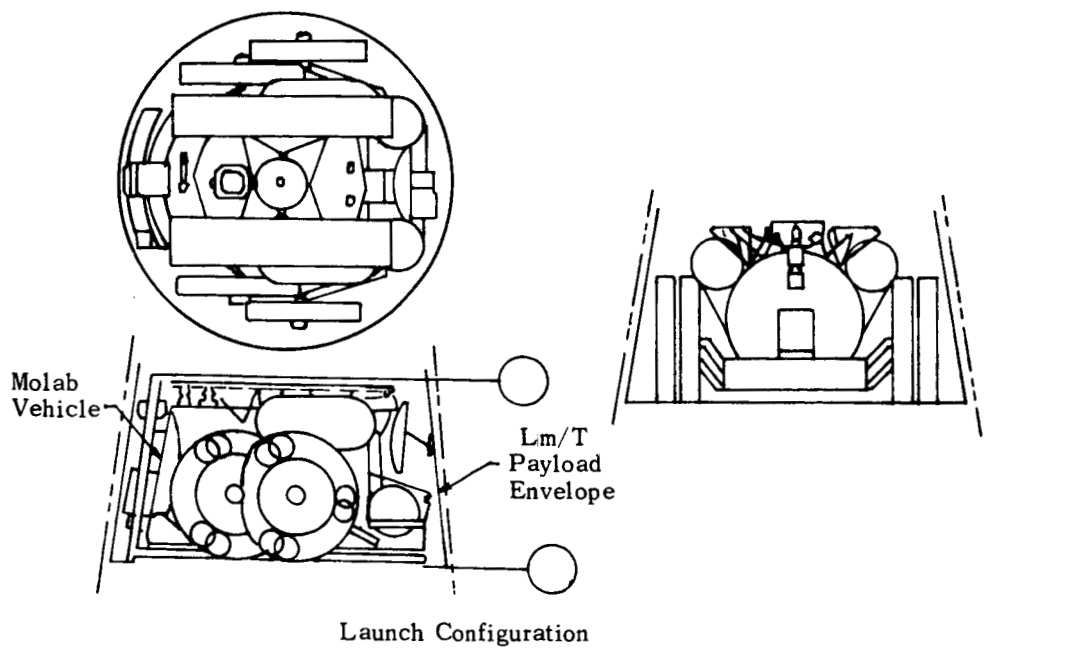


FIGURE 11 - TYPICAL MOLAB CONFIGURATION (BENDIX)
4 WHEEL DRIVE TYPE.

MANNED ROVING VEHICLE CABIN – THREE MAN

Date
May 66

Rev.

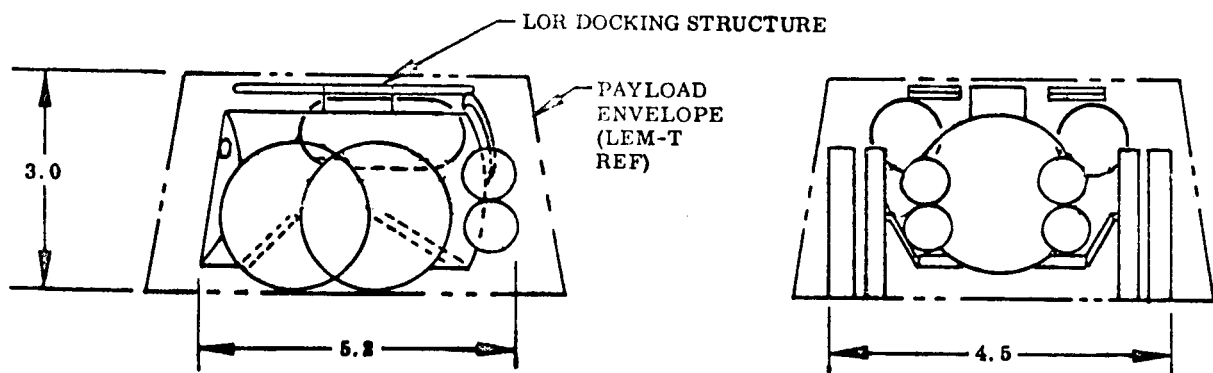
GENERAL PERFORMANCE

General Performance

Item	
Crew Size	3
Staytime (Nominal), Days	21
Range (Nominal), km	900
Speed (Average), kph	10
Experiment Power (Nominal), kw-hr	112
Scientific Payload (Max.), kg	320
System Mass, kg (not incl. payload)	3,810

Note: Staytime shown is in addition to 7 days emergency layover with no travel.

LAUNCH CONFIGURATION (Dimensions in Meters)



MASS SUMMARY

Mass Summary (Kilograms)

Item	Mass
Nonexpendables	
Structure	636
Power Supply	220
Mobility	1,485
Life Support	324
Astrionics	320
Total Nonexpendables	2,985
Expendables (Usable & Unusable)	
H ₂ Capacity (Max.)	88
O ₂ Capacity (Max.)	
Power	347
Metabolic (Incl. cabin loss)	216
Others (food, LiOH, etc.)	174
Total Expendables (Max.)	825
System Mass	3,810

FIGURE 12 - TYPICAL PARAMETRIC DATA SHEET
FOR A 3-MAN - 21 DAY MOLAB

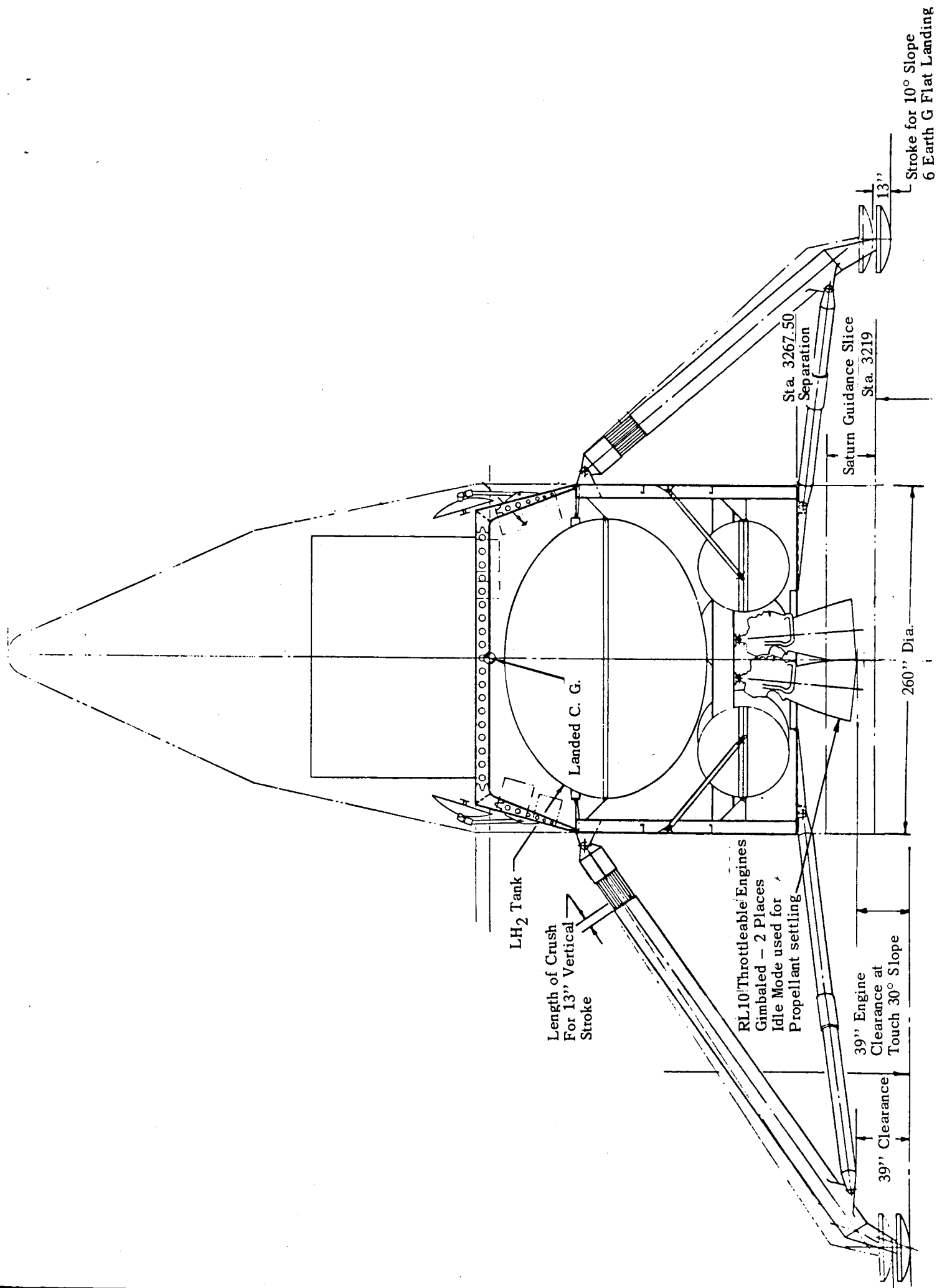


FIGURE 13 - TYPICAL SINGLE STAGE CRYOGENIC LUNAR LOGISTICS VEHICLE

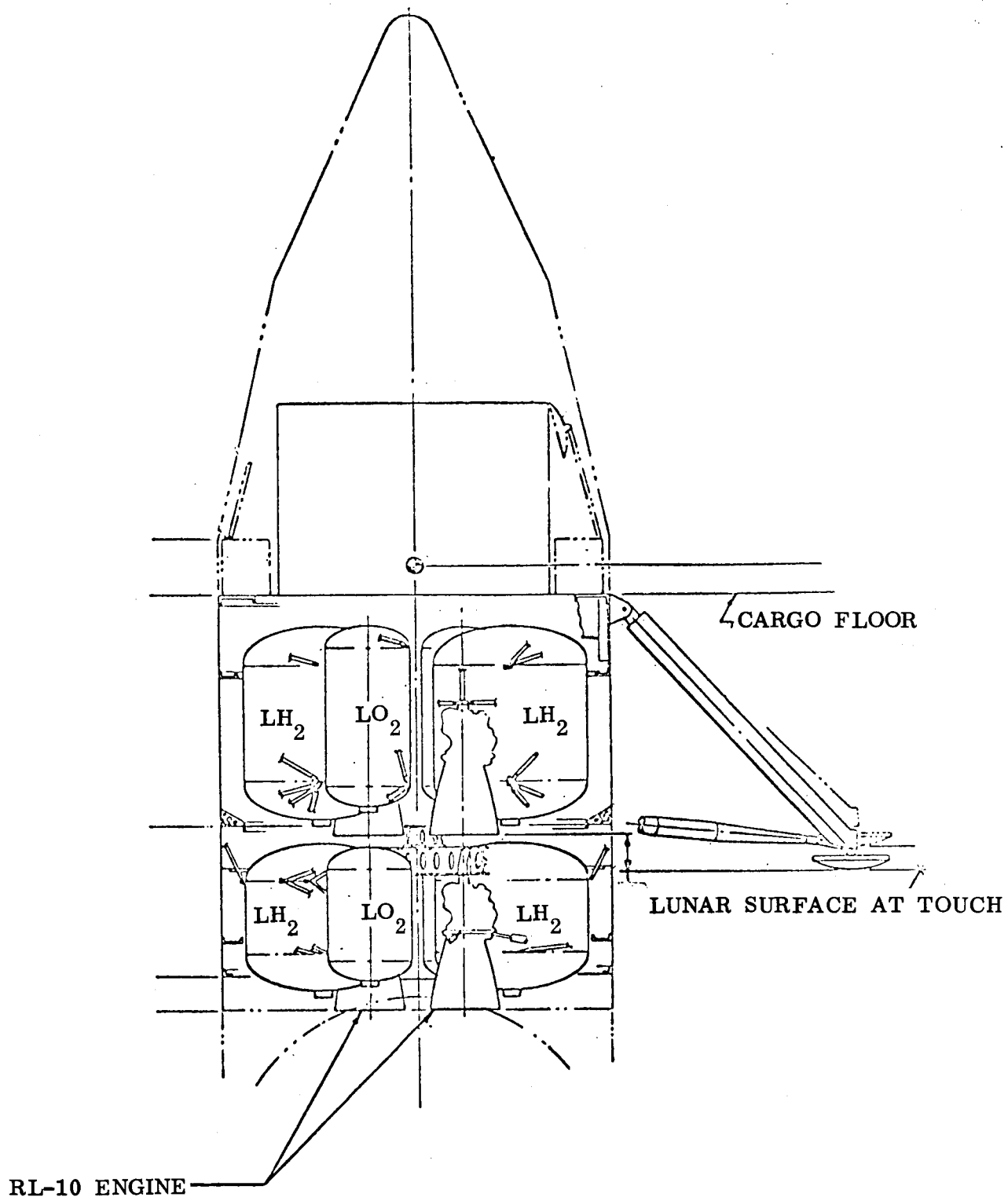


FIGURE 14 - TYPICAL TWO STAGE
CRYOGENIC LUNAR LOGISTICS VEHICLE

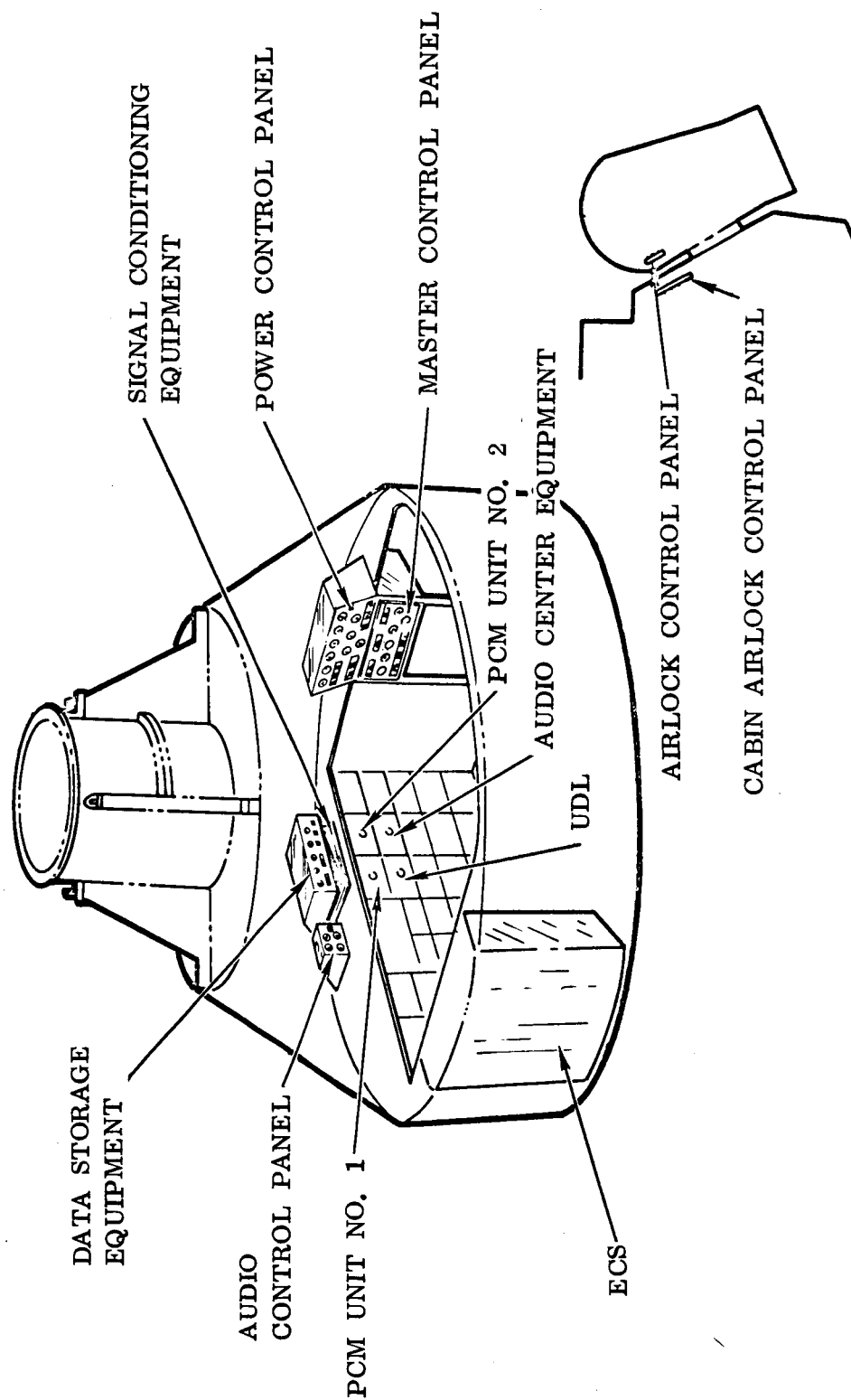


FIGURE 15 - COMMAND MODULE SHELTER CONCEPT

APOLLO DERIVATIVE MISSION EQUIPMENT

LUNAR SHELTERS AND COMBINED SHELTER/MOBILITY SYSTEMS

<u>Name</u>	<u>Description</u>	<u>Pertinent Features</u>	<u>Nominal Weight-Lbs</u>	<u>Data Source</u>
LM Shelter (Figure 1)	LM ascent stage with: (1) ascent engine removed (2) empty main propellant tanks	Planned for AAP Fuel cells added Internal volume-225 ft ³	6700 lbs	Reference 11
CM Shelter (Figure 15)	CM modified for use as a lunar shelter	Delivery on a LM Truck Internal volume--306 ft ³	8000 to 8500 (estimated)	Reference 12
MOLEM (Figure 5)	LM shelter on a mobile chassis	Delivery on a LM Truck	9100	Reference 2
MOCOM (Figure 6)	CM shelter on a mobile chassis	Delivery on a LM Truck	9500	Reference 6

LUNAR LOGISTICS VEHICLES (LLV)

<u>Name</u>	<u>Description</u>	<u>Pertinent Features</u>	<u>Landed Payload Capability-Lbs</u>	<u>Data Source</u>
LM Truck (Figure 2)	LM descent stage with payload platform	Basic type early LLV RCS and guidance added	10,300	Reference 11
SM Lander (Figure 3)	Service Module with landing gear	Needs throttleable engine 154 inch payload diameter	11,000	Reference 3
LASS (Figure 4)	S-IVB spent stage with landing gear	Advanced J-2 engine required 260 inch payload diameter	16,000 to 19,000	Reference 4

TABLE 1

GRUMMAN MOLEM OPERATING CHARACTERISTICS

	Configuration	
	Minimum Change	Moderate Change
Category:	Surface Vehicle	Surface Vehicle
Crew Size:	2	2
Size:		
Package Volume	Within SLA	Within SLA
Required Station Envelope	198-312.5	198-312.5
Cabin Type:	Closed	Closed
Payload:	5 psia, O ₂	5 psia, O ₂
Type	Scientific	Scientific
Weight	750 lbs	750 lbs
Volume	70 ft ³	78 ft ³
Vehicle Weight:	9,067 lbs	9,136 lbs
Mission Duration:	14 days, 250 nm	14 days, 250 nm
Maximum Speed:		
Level Terrain, Soft Soil (ELMS)	6.5 mph	10 mph
Level Terrain, Compacted Soil	16 mph	23 mph

TABLE 2